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TIME IMPACT OF EXPANDED PROCESS CONTROL PROCEDURES (EPCP)

by

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13. ABSTRACT (maximum 200 words)

The United States Navy (USN) surface ships must receive maintenance and modernization in order to attain their expected lifetimes and the level of readiness that the Navy requires. A program called Enhanced Process Control Procedures (EPCP) aims to decrease the number and frequency of critical systems failures occurring during the maintenance availability. This research aims to identify the costs and benefits of the program, determine other factors that cause critical systems downtime and maintenance availability extensions, and provide recommendations to improve the EPCP program.

The costs of the program are the increased time required to complete the work, greater funding requirements, decreased flexibility, and possible impact on the technicians. Analysis of EPCPs over an 18-month period between 2012 and 2014 revealed that the total time to develop, review, and correct the EPCP documentation averaged 28 days, with a standard deviation of 26 days. The 75% confidence value for the total administrative time required of an EPCP was almost 36 days. The author recommends using this time duration when planning a maintenance availability. The benefits of the program are a larger degree of accountability, lower probability of human error, and greater communication and coordination.

The review of EPCPs suggest that the efficiency of the EPCP program could be improved by increasing the number of reused EPCPs, decreasing the number of EPCP errors, involving subject-matter experts in EPCP documentation, and decreasing the EPCP administrative temporal impact. Additionally, the author recommends the USN utilize an improved record keeping system to minimize delays in maintenance availabilities.

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TIME IMPACT OF EXPANDED PROCESS CONTROL PROCEDURES (EPCP)

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LIST OF ACRONYMS AND ABBREVIATIONS

BMD	Ballistic Missile Defense
CG	Cruiser
CHENG	Chief Engineer
CNO	Chief of Naval Operations
CNRMC	Commander, Navy Regional Maintenance Center
CWP	Controlled Work Packages
DDG	Destroyer
EMMI	Energy, Matter, Money, and Information
EPCP	Expanded Process Control Procedures
FME	Foreign Material Exclusion
FWP	Formal Work Package
GAO	Government Accountability Office
HM&E	Hull, Mechanical, and Electrical
MRG	Main Reduction Gear
MPDE	Main Propulsion Diesel Engine
NAVSEA	Naval Sea Systems Command
NRMO	NAVSEA Regional Maintenance Office
NSSA	Norfolk Ship Support Activity
OQE	Objective Quality Evidence
QA	Quality Assurance
PMS	Planned Maintenance System
RMC	Regional Maintenance Center
RTS	Ready to Start
SSLCM	Surface Ship Life Cycle Management
SUPSHIP	Supervisor of Shipbuilding
TWD	Technical Work Documents
USN	United States Navy

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EXECUTIVE SUMMARY

The United States Navy (USN) fleet of surface ships must receive maintenance and modernization in order to attain their expected lifetimes and the level of readiness that the Navy requires. Maintenance refers to the work done on existing equipment to extend the life of the systems and ensure that the systems operate as desired. Modernization is the work accomplished to extend the life of the ship and to ensure it is better able to complete its missions.

During these periods of maintenance and modernization, the goal is for the work to be completed on time and within the budget, especially on maintenance availabilities. Maintenance availabilities are extended periods of work during which the ship usually cannot go underway. A program called Enhanced Process Control Procedures (EPCP) is used to help achieve these goals. A significant benefit of the EPCP program is that it aims to decrease the number and frequency of critical systems failures occurring during the maintenance availability. The EPCP program mandates the use of approved procedures in order to conduct work on critical systems. This research evaluated the time impact of the EPCP program.

The costs of the EPCP program are the increased time required to complete the work, greater funding requirements, decreased flexibility, and possible impact on the technicians. The benefits are a larger degree of accountability, lower probability of human error, and greater communication and coordination. Testing failures and parts availability may also contribute to critical systems failures and maintenance availability extensions. Upon a testing failure, a solution must be implemented, and the test must be re-done. Problems with parts availability can include delays in receiving the parts, mistakes in the parts ordering process, and a needed part may be ordered more than once.

This study looked at the time impact of EPCPs by examining EPCP records used in Norfolk Ship Support Activity (NSSA) over an 18-month period between 2012 and 2014. The time to develop, review, and correct an EPCP were evaluated, as well as the

total time to complete an EPCP. The analysis found no statistically significant trends in the total administrative time, or in the development, reviewing and correction phases. The average total times to develop, review, and correct the EPCP documentation was 28 days, and the standard deviation was 26 days. The 75% confidence value for the total administrative time of an EPCP is almost 36 days. The author recommends using this time duration when planning a maintenance availability. Using an estimate based on a 75% confidence level limits the risk of underestimating the duration to 25%. Under estimating the total time to obtain an approved EPCP will likely result in schedule delays and increased costs.

Record keeping is important for management to be able to provide adequate oversight on a complex system. The accuracy of the efficient record keeping system can impact delays in maintenance availabilities. A GAO report in 1991 found that the USN record keeping system did not have accurate data. The GAO also observed similar deficiencies in 1976 and 1982. The USN did make improvements to its system after 1976 and 1982, but significant problems remained in 1991. The author was unable to obtain data to compare the current USN record system with the system in place in 1991.

Based on observations of the EPCP process, the author suggests that the EPCP program could be more efficient by increasing the number of EPCPs that are reused, decreasing the number of EPCP errors, involving subject-matter experts in EPCP documentation, and decreasing the EPCP administrative temporal impact. Additionally, the author recommends the USN continue to improve the record keeping system to minimize delays in maintenance availabilities.

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I. INTRODUCTION

The United States Navy (USN) fleet of surface ships must receive “maintenance and modernization” in order to attain their expected lifetimes and the level of readiness that the Navy requires. The United States Navy’s Fleet Modernization Program is the “primary vehicle for updating the offensive, defensive, and operating systems installed on each of its ships” (United States Government Accountability Office 1991, 1). The maintenance and modernization work that is not tasked to the ship’s crew is typically accomplished during a process called maintenance availability. A maintenance availability “is the time a U.S. Naval ship undergoes repairs and alterations to return it to a fully operational status and ensure complete mission readiness” (Lawson 2012c).

Maintenance refers to the work done on existing equipment to increase the likelihood that the system will reach its intended lifespan and to ensure that the systems operate as desired. The United States Navy’s Fleet Modernization Program has “three goals: to improve ships’ capabilities and material condition, to increase fleet readiness by improving standardization of ships, and to improve the safety, reliability, reparability, and habitability” (United States Government Accountability Office 1991, 1). According to O’Rourke (2010), modernization’s goal is also to conduct work to allow ships to be cost-effective throughout their service lives, which can be 35 or 40 years. The USN is conducting modernizations on Ticonderoga-class guided missile cruisers to reach the 35-year service life that the USN desires (United States Navy 2013). The difference between maintenance and modernization lies in the methods each use. Modernization aims to accomplish the goals through replacing existing systems and components with newer or upgraded versions. Being cost-effective means that ships cost less to operate, maintain, and modernize. Through modernization, “ships may be operated with a smaller crew, thereby reducing their annual operations and support (O&S) costs.” An example of the Navy’s modernization efforts is that the USN intends to modernize their destroyers (DDGs) and cruisers (CGs) by using an open architecture (OA). This modernization means that these ships will shift to using “non-propriety computers and software, permitting the Aegis system to be updated over the remainder of the ships’ lives more

easily and less expensively, using contributions from a variety of firms" (O'Rourke 2010, 3). Another example improving cost-effectiveness is to improve the ship's fuel efficiency by adding electric-drive propulsion equipment to ensure the mechanical-drive components fully interconnect (O'Rourke 2010).

According to O'Rourke, modernization is also conducted to add or capabilities to the ship or improve the ship's capabilities. One main goal of the USN's DDG and CG modernization program is to improve the ship's combat capability. This improvement will help ensure that the ships will be able to complete their mission throughout their intended service lives. One example of this type of modernization is the goal of adding ballistic missile defense (BMD) capability to the 62 Aegis destroyers and 22 cruisers (O'Rourke 2010).

For the USN's Aegis ships, modernization comprises three categories: hull, mechanical, and electrical (HM&E) and combat systems. For each category, the USN desires to add more capable systems and components (O'Rourke 2010, 3). For Aegis ships, the HM&E modernization is planned to occur first, followed by the combat systems modernization two years later. This approach may imply that HM&E equipment tends to require maintenance and modernization before combat systems equipment does. HM&E may require maintenance and modernization earlier due to use and corrosion from being at sea. Splitting the maintenance and modernization work into categories will tend to make the maintenance availabilities more manageable. However, the risk of needed work being missed due to the work belonging in the wrong category is higher.

According to Roberts (2009), the USN values the tasks of maintenance and modernization with such importance that the Surface Ship Life Cycle Management (SSLCM) Activity was created on May 8, 2009. SSLCM is in charge of the Class Maintenance Plans for the non-nuclear surface ships. SSLCM is tasked with ensuring that the material condition of the surface ships allows the ships to achieve their desired expected service life. Rear Admiral James McManamon, deputy commander for surface warfare (SEA 21) stated, "to meet this goal [the Navy having 313 ships], we need to continue to maintain and efficiently manage our existing ships" (Roberts 2009).

The Regional Maintenance Centers (RMCs) help accomplish these maintenance and modernization goals. There are three levels of maintenance: organizational, intermediate, and depot level. Organizational maintenance refers to the work that is conducted frequently and is the least complicated of the three levels. Organizational maintenance is conducted on the ship. Intermediate maintenance is conducted in specialized material shops. Typically, many ships use the same specialized shop. The Intermediate maintenance tends to be more involved than the Organizational maintenance. Depot maintenance occurs in the manufacturer's specialized shops. This type of work is generally the most complicated of the three levels of maintenance.

The RMCs conduct maintenance support that includes intermediate level maintenance and oversight of depot-level maintenance, which is executed by the private sector (Engineering Duty Officers 2012). RMCs aim to complete the ship maintenance on schedule and within budget, while meeting the requirements of the quality requirements (Commander, Navy Regional Maintenance Center 2013). This goal indicates that cost, schedule, and performance are important to the RMCs. The RMCs seek to keep on schedule since maintenance availability extensions tend to increase costs and delay subsequent surface ship maintenance availabilities. This delay would also postpone the ship that is in the maintenance availability from executing its following mission.

The Expanded Process Control Procedures (EPCP) program is used by the RMCs to help accomplish their stated goals by decreasing the frequency of critical system failures, which tend to increase monetary costs and probability of exceeding the desired completion date. The author was not able to obtain evidence that the EPCP program achieved the desired objective of reducing critical systems failures. If the EPCP program is not achieving the USN's desired objectives, the program may not be helping the RMCs to complete ship maintenance availabilities on time and within budget. The EPCP may even be hindering the successful execution of ship maintenance availabilities. If the EPCP program achieves the USN's desired objectives, the program likely contributes towards ensuring that each ship maintenance availability is completed on time and under budget. This paper identifies the costs and benefits of the EPCP program and examines the time impact of the EPCP process. Since a major goal during a maintenance

availability is to prevent delays in the completion of the maintenance and modernization period, testing failures parts availability and scheduling will also be investigated.

A. THE EPCP PROGRAM

The USN has experienced repeated problems and failures on some of the critical systems onboard the surface ships (Commander, Navy Regional Maintenance Center 2012). A critical system is "a propulsion or mobility system for which improper execution of required complex work will cause unacceptable Fleet Readiness impacts including mission delay, diminished Operational Availability, and/or excessive repair costs" (Naval Sea Systems Command 2013). Critical systems which do not function properly have a high probability of preventing a surface ship from going to sea. All classes of surface ships have the following critical systems: Main Reduction Gear (MRG), MRG Lube Oil System, and the Steering Systems (Naval Sea Systems Command 2013). Each specific class of surface ship may have additional systems that are classified as critical (Naval Sea Systems Command 2013).

The USN noticed "recurring problems especially on the Main Propulsion Diesel Engines (MPDEs) and the MRGs" (Commander, Navy Regional Maintenance Center 2012). As a result, the USN experienced excessive costs ships that had a decreased ability to go underway and deploy (Commander, Navy Regional Maintenance Center 2012). The USN believes that these recurring problems are caused by insufficient work processes, quality management programs, and government oversight (Commander, Navy Regional Maintenance Center 2012). The EPCP program is a management process than the USN implemented to reduce the frequency of critical system failures during maintenance availabilities.

1. Intent

The EPCP program attempts to create processes to prevent these recurring problems (Commander, Navy Regional Maintenance Center 2012). EPCPs were created to reduce these issues by "improving maintenance practices and gathering objective material evidence" (Lawson 2012a). Norfolk Ship Support Activity's (NSSA) Aircraft Carrier/Amphibious Ship division head, Commander Andy Johnson, said, "EPCPs

establish the appropriate maintenance practices and sequences for optimal performance results" (Lawson 2012a). The EPCP looks to address the accountability record keeping problems that may have been present and contributed to the failures and problems (Commander, Navy Regional Maintenance Center 2012).

EPCPs also decrease risk and provide the surface navy's leadership and the surface maintenance community's leadership with greater confidence in the maintenance work. Commander Andy Johnson said, "The use of EPCPs provide greater assurance of successful operation at full-rated capacity after overhaul" (Lawson 2012a). This statement indicates that the operational testing occurring after maintenance and modernization work is completed may tend to fail more frequently than the USN's leadership requires. An operational testing failure is an unsuccessful attempt to meet the requirements of test of a certain system. The test is generally required after major maintenance has occurred or the system has been in an inoperative state. A ship's successful operation after overhaul is not guaranteed. The risk of an unsuccessful operation appears to be high enough that Commander Johnson would identify the greater assurance that EPCPs provide as a benefit of the program. These operational testing failures usually lead to increased cost and greater time required to repair.

2. EPCP Document Generation and Approval Process

According to the Navy Regional Maintenance Center, the EPCP program helps to ensure that completed technical work documents (TWDs) have the instructions and information to achieve a successful work certification (Lawson 2012a). Work certification is the documentation that proves that the required work has been completed according to all requirements. Any required testing results also make up the work certification.

EPCPs "establish the appropriate maintenance practices and sequences for optimal performance results" (Lawson 2012a). Rear Admiral Gale, Commander, Navy Regional Maintenance Centers (CNRMC) stated, "EPCPs create a series of TWDs that provide sufficient detail, including all the necessary objective quality evidence (OQE) required, to ensure the completion of the TWD accurately" (Lawson 2012a). The TWDs

explain what work must be accomplished and how it should be done. Additionally, TWDs are followed in a methodical manner (Lawson 2012a). OQE serves to verify that the work is completed according to specification. OQE consists of the completed TWDs and test results (Lawson 2012a). The completed TWDs and test results are reviewed to ensure they followed all instruction, regulations, and specifications (Lawson 2012a). The completed TWDs make up the OQE that certifies that the work and tests have been accomplished as required (Lawson 2012a). Rear Admiral Gale believes that "This documentation process provides all information needed to certify that work completed within a ship's availability is in compliance with the existing technical requirements and greatly enhances the overall quality of the repair" (Lawson 2012a).

An EPCP explains the "precautions for personnel, equipment, and sanitation and the prerequisites and initial conditions that must be completed prior to commencing work on the critical system" (Commander, Navy Regional Maintenance Center 2012). The EPCP identifies the "required personnel qualification needed for members of the work team to participate in the maintenance action, the methodologies to handle hazardous materials," the required materials, and the applicable technical documents (Naval Sea Systems Command 2013). The EPCP also contains the procedure, which identifies the required tasks and the order to complete the tasks (Commander, Navy Regional Maintenance Center 2012). The procedure contains steps to perform and tests and inspections to conduct.

The prime contractor of each critical system generates the EPCP for that critical system. The RMC Engineering and Quality Assurance (QA) departments are tasked with approving the contractor's EPCP. The contractor must have an approved EPCP for a critical system prior to conducting scheduled work on that system (Commander, Navy Regional Maintenance Center 2012).

3. Execution of EPCP

According to the Navy Regional Maintenance Center, the contractor must have a copy of the approved EPCP with him while performing the critical system work. The contractor must mark on the EPCP after commencing and completing each step. If a

scenario arises that work or a test cannot be completed, the contractor must stop work and notify his/her supervisor (Commander, Navy Regional Maintenance Center 2012). If changes are required, they must be reviewed to ensure they are following technical requirements by the waterfront chief engineer (CHENG) from the RMCs or Supervisor of Shipbuilding (SUPSHIP) (Lawson 2012a).

If unscheduled work on a critical system must occur, that work becomes emergent (Commander, Navy Regional Maintenance Center 2012). Emergent work may occur without an approved EPCP if the RMC Commanding Officer concurs (Commander, Navy Regional Maintenance Center 2012). The EPCP must still be prepared before work begins (Commander, Navy Regional Maintenance Center 2012). However, preparing the EPCP shall not cause the work to be delayed (Commander, Navy Regional Maintenance Center 2012). If a contractor conducts work without an approved EPCP, that work "must be continuously monitored and all actions taken observed and recorded by the contractor QA personnel and the contractor work center supervisory personnel" (Commander, Navy Regional Maintenance Center 2012). The local RMC "shall perform all appropriate inspections necessary to certify the work" and must "monitor the work in progress to provide the necessary oversight and certification" (Commander, Navy Regional Maintenance Center 2012). When the work is completed, "the actions observed and recorded must be incorporated into the EPCP" (Commander, Navy Regional Maintenance Center 2012).

B. CONTROLLED WORK PACKAGES

In addition to the EPCP program, the USN uses Controlled Work Packages (CWPs). An objective comparison between the EPCP and CWP program would be interesting, but the author does not have enough data on the CWPs to conduct this comparison. CWPs are "a set of detailed instructions for performing a maintenance action" (Bischoff 1990). They consist of the "records that provide the Objective Quality Evidence (OQE) necessary to certify that the completed maintenance was authorized, required tests were completed and work was certified" (Executive Director 2013, V-I-FWD-B-4). OQE refers to "any statement of fact, either qualitative or quantitative,

pertaining to the quality of a product or service based on observations, measurements, or tests which can be verified" (PM-Essentials 2014). For surface ships, OQE serves as the proof and verification that the completed work meets the USN's requirements. OQE provides confidence that system will work according to specification and will not malfunction as a result of the recent work and repairs. In addition to OQE, CWPs consist of Formal Work Packages (FWPs) (Executive Director 2013, V-I-FWD-B-4). An FWP comprises of the "written instructions for use in production and repair, delineating all the essential elements and guidance necessary to produce acceptable and reliable products" (Executive Director 2013, V-I-FWD-B-6). Some of the significant components of the FWP include "material, responsibilities, precautions, initial conditions, procedures, test and inspection, and system restoration" (Executive Director 2013, V-I-2-7). FWPs contain the instructions for desired work, and the OQE serves as the certification that the work meets the Navy's needs.

CWPs are not required for all work requests. A CWP is "required when higher authority requires a record of repairs/maintenance for fabrication, repair, installation, inspection and testing process for specific systems/components" (Executive Director 2013, V-I-2-4). There are 28 different scenarios that require CWPs (Executive Director 2013, V-I-2-2). These scenarios relate either to nuclear propulsion systems, systems involving dangerous chemicals, such as Freon and flammable liquids, critical systems, and tasks, such as electric motor rewind and welding or brazing (Executive Director 2013, V-I-2-1-V-I-2-2).

The FWP is "prepared by the work center responsible for accomplishing the work" (Executive Director 2013, V-I-2-7). CWPs must be approved "prior to the performance of the work" (Executive Director 2013, V-I-2-12). During an "Internal Screening, the lead planner reviews each work request flagged for QA and other special requirements" (Bischoff 1990, 56). The lead planner decides if the flagged work request requires a CWP (Bischoff 1990, 56). Also, the "QA Office conducts an independent review before a CWP is released to the lead work center" (Bischoff 1990, 58). The Quality Assurance Officer (QAO) approves or disapproves the CWP (Executive Director 2013, V-I-2-12). Once the CWP is "approved and delivered to the lead work center, the

work center can start the work" (Bischoff 1990, 58). CWPs contain "lists of reference and enclosures, prerequisites, precautions, shop responsibilities, step-by-step instructions, and QA signature requirements" (Bischoff 1990, 58). Once the CWP is approved, the work may be performed. The CWP must "be at the job site during the performance of the work" (Executive Director 2013, V-I-2-12).

C. COMPARISON OF EPCP AND CWP

In both the EPCP and CWP, the QA department has a major role in approving the work procedures. Another similarity is that, except for rare exceptions, the contractor cannot start work before the EPCP or CWP are approved. Both EPCPs and CWPs share similar negative aspects. CWPs are "complex and costly" and "the risk of schedule overrun is high" (Bischoff 1990, 28). Schedule overruns are likely to occur if a CWP is required for work that is identified late (Bischoff 1990, p.31). EPCPs and CWPs are complex due to the detailed instructions that are required for the written procedures. They are costly since they require contractors to expend man hours in the creation and approval of the documents and the execution of the procedures. Schedule overrun is a risk with EPCPs and CWPs since their requirements may lead to work starting later. They may also cause work to progress at a slower pace.

The reason for the development of the EPCP program instead of continuing the use of the CWP program is not obvious to the author. Looking at some key differences between the CWP and the EPCP may reveal some possible reasons. The party that generates and approves each document is different. Using the CWP program, the ship's force work center responsible for the system or component generates the CWP. Under the EPCP program, the prime contractor generates the EPCP. This seems to indicate that the EPCP program is intended to be used when the ship is under the control of the contractor during maintenance availabilities, and the CWP program applies to the periods when the ship's crew has control of the ship. This means that the EPCP is conducted during private depot level maintenance and the CWP is conducted during intermediate and public depot level maintenance.

Another key difference is that the CWP program applies to Nuclear Propulsion systems, while the EPCP program does not. Additionally, the EPCP program only applies to the ship's critical systems. The CWP program is also used on critical systems; however, it also applies to systems and components that are not considered critical.

It may be that the EPCP is a more specific type of CWP that includes changes in who writes and approves the written procedures. The intended improvement for the changes in the EPCP may have been to obtain more reliable accountability from the prime contractors and the USN technical authority.

D. RESEARCH QUESTIONS

The goal of this study is to identify the benefits and costs of the EPCP program and evaluate the time impact of the EPCP process. Additionally, the impacts of scheduling, testing failures, and parts availability on maintenance availability delays will be investigated.

II. BENEFITS AND COSTS OF THE EPCP PROGRAM

There are benefits and costs that result from the implementation of the EPCP program in terms of the successful completion of USN surface ship maintenance availabilities. A successful completion of a maintenance availability means that the desired work is done within the allocated budget and on time.

A. BENEFITS

The EPCP program is believed to "provide a return to the fleet in terms of operational availability through to the end of the ship's service life," according to Commander Johnson (Lawson 2012a). The benefits of the EPCP program include a system that is more accountable, a decrease in the probability of technician human error, and greater communication and coordination.

1. Greater Accountability

The EPCP program increases the level of accountability. By mandating that all work on critical systems must be conducted by following procedures that have been written and approved by a technical authority, management is better able to monitor and evaluate the process. Problems that occur on a critical system can be examined to determine which portion(s) of the process contributed to the critical system failure. Management can determine if the complications are due to an incorrect EPCP being written and approved, a technician improperly following the EPCP, inadequate oversight by the contracting company and government representatives, or a combination of these causes.

Without the EPCP program, an investigation would have a more difficult effort of determining what the technician working on the critical system was attempting to accomplish and what he actually did. The approved EPCP clearly indicates which work the technician is tasked to perform. Since the EPCP also includes a detailed list of procedures that the technician is required to indicate once performed, an investigation is more likely to determine which task caused the fault or failure.

2. Lower Probability of Human Error

The EPCP program tends to lower the chance of human error since it forces the technician to rely less on her memory and more on following written procedures. Commander Johnson referred to the first use of the EPCP program on an overhaul of USS Carter Hall’s two MPDEs when he stated, “The use of EPCPs provide greater assurance of successful operation of diesel engines at full-rated capacity after overhaul” and “At the completion of the production effort, there was high confidence in the material condition of both overhauled engines to perform at maximum rated horsepower” (Lawson 2012a). Commander Johnson also stated that “execution of work within the EPCP process was more methodical than previous methods of overhaul” (Lawson 2012a). The EPCPs supported “the high confidence in the overhauled engines with both engines completing their break in period in five days, nearly 50 percent shorter than the average time required, with only minor adjustments needed during the Sea Trials of USS Carter Hall” (Lawson 2012a). Commander Johnson also noted, “There is high confidence that both of these overhauled engines will be able to meet their service life expectations without major issue resulting from the rigid overhaul procedures and quality inherent in the EPCP process” (Lawson 2012a).

A possible criticism of the EPCP program may be that it does not use the technician’s experience since the worker is following written procedures. However, the author believes that it is not accurate to argue that mandating following set procedures disregards the technician’s experience. The technician’s experience should be present in the written procedures of the EPCP. Additionally, the technician’s experience allows the correct execution of the EPCP procedures. A technician with suboptimal experience with a system will have greater difficulty understanding and adhering to the written procedures. A technician without adequate experience would also be less likely to recognize issues and problems during the execution of the work.

Numerous experts in the military are required to conduct tasks according to approved checklists. One of the main reasons for this requirement is the acknowledgement that humans, even those with significant experience, make mistakes. A significant contributor to these mistakes is that humans do not have perfect memories and

can forget to perform critical steps. The use of checklists decreases the chance and number of occurrences these forgotten steps.

Using the EPCP also decreases the reliance on a technician’s memory. Instead, the technician must follow each written step. This decreases the chance that an important step, whose omission may bring down a critical system, will be forgotten.

3. Greater Communication and Coordination

The EPCP program facilitates necessary communication between the contractor company management, the contractor technician, and the government representatives. It accomplishes this through incentives. These three stakeholders would be typically incentivized to communicate more often and with greater efficacy. The dialogue among the three stakeholders is crucial to accomplish the necessary work on time and in the government’s desired manner. By mandating that the EPCP must be written and approved prior to the commencement of work, these three stakeholders should recognize that this document must be accurate and reflect their desires. If this realization does not happen, that stakeholder is likely to be held accountable for failures on that critical system.

When the contractor company management, contractor technicians, and government representatives realize these incentives, they will tend to be more eager and willing to communicate and coordinate with the other stakeholders to ensure that the EPCP document is accurate and achievable.

B. COSTS

The costs of the EPCP program include the additional time to complete the required work, increased funding required to execute the EPCP program, and a decreased amount of flexibility in executing work on critical systems during ship maintenance availabilities.

1. Increased Time Required to Complete Work

The EPCP program tends to increase the amount of time to complete maintenance on critical systems when compared to a system that does not require approved procedures. The increased amount of time is due to the procedures and steps required to be completed before work can commence. Commander Johnson stated that EPCPs “required the availability duration be extended to allow for the completion and certification of the work performed” (Lawson 2012a). The tendency of the EPCP program to increase the time required is due to generating, reviewing, and correcting the EPCP documentation and also due to executing the work in accordance with the approved EPCP TWD. To evaluate these processes, data from Norfolk Ship Support Activity was obtained. The data covered EPCP TWDs during fiscal years 2012–2014.

2. Increased Funding May Be Required

The EPCP program should require increased funds to execute the necessary procedures and steps. A large portion of these costs are due to the extra man hours needed to generate and approve the EPCP for all maintenance work to be performed a ship’s critical systems. As will be discussed later in the paper, the average administrative time for an EPCP in Norfolk Ship Support Activity is 28 days. Assuming that a minimum of two hours per day is allocated to this single EPCP, each EPCP averages around 56 man hours. At an hourly wage of $33.63 for shipyard engineers, each EPCP has an estimated average administrative personnel cost of $1883.28. The average number of EPCPs per fiscal year at Norfolk Ship Support Activity was 362. Therefore, the administrative personnel cost per fiscal year at Norfolk Ship Support Activity is estimated to be $681,747 dollars. Additionally, the technician should tend to expend more man hours to execute the work according to the approved procedure than if the technician conducted the work based on his/her knowledge and experience.

Another cost that is incurred by the EPCP program is the cost to implement and maintain the program. The implementation cost is a sunk cost since it has already occurred. The maintenance of the program includes training personnel to use adhere to the EPCP program. Personnel must expend time to gather and track metrics relating to

the EPCP program. Additionally, the USN leadership must track and update the EPCP program to ensure that it is meeting the fleet’s needs.

3. Decreased Flexibility

The EPCP program lowers the amount of flexibility afforded to the contractors working on the ship’s critical systems. Since the contractor must, in most cases, follow the approved EPCP procedures, he/she is less able to rely on his maintenance experience to react to the reality of the state of the equipment. However, the EPCP program tends to lower the chance of human error since it forces the technician to rely less on her memory and more on following written procedures.

4. May Generate Disincentives for Technicians

Although many technicians are experts on systems and equipment within their domain, they are not likely to know everything about the systems and equipment. Technicians may not have encountered and fixed every fault, conducted every type of maintenance and modernization, or used the system in every possible way. This reality indicates that even though perfect knowledge tends to be unattainable, the technician should strive towards that goal. Striving for perfect knowledge helps ensure that the technician is most prepared to perform maintenance and modernization in an efficient manner.

The EPCP program may have an unintended consequence of reducing the responsibility of the technician. Instead of being the sole source to conduct a specific type of work, the technician must follow an approved set of procedures. The technician is doing his/her job as long as the procedures are followed. Since the technician no longer has to come up with the plan and solution, the risk is greater that he/she will become more disengaged.

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III. ANALYSIS OF THE TIME IMPACT OF EPCP

A. TIME TO GENERATE, REVIEW AND CORRECT THE EPCP DOCUMENTATION

Norfolk Ship Support Activity (NSSA) provided data concerning EPCPs for a portion of 2012, all of 2013, and a portion of 2014. This data contains the date that the development, reviewing and correction phase commenced for each EPCP at NSSA. The data also shows the duration of each phase for each EPCP and lists the ship and system to which each EPCP belonged. NSSA's data indicates whether the EPCP was a reuse EPCP, if the reuse EPCP was changed, and if there were errors in the EPCP. This data was used to calculate the time impact of the EPCP documentation phases.

a. Time to Develop the EPCP Documentation

To arrive at an approved EPCP, the TWD must be generated or developed. The average time to develop an EPCP when averaged across each day was 23.0 days, with a standard deviation of 29.3 days. There were four data points that were more than three standard deviations greater than the mean. The reason for such a large deviation from the mean is unknown to the author. These four observations were discarded from this analysis. The updated average time to develop an EPCP when averaged across each day was 21.8 days, with a standard deviation of 25.7 days. The minimum was zero days, and the maximum was 104 days. There were 423 observations. The R-squared value was 0.0511, and indicates that there is not a statistically significant trend over time for this data. The development time was averaged per month. The average time to generate an EPCP when averaged across each month was 18.0 days, with a standard deviation of 10.5 days. This data is shown in Table 1 and graphed in Figure 1. Figure 2 shows the data plotted daily. Figures 1, 2 and 3 show the data after discarding the outliers.

Average Time for NSSA to Develop an EPCP TWD per Month		
Year	Month	Average Time to Develop [Days]
2012	Nov	15.2
2012	Dec	-
2013	Jan	49.0
2013	Feb	9.5
2013	Mar	19.6
2013	Apr	23.8
2013	May	22.5
2013	Jun	29.8
2013	Jul	15.8
2013	Aug	8.9
2013	Sep	9.6
2013	Oct	11.4
2013	Nov	24.4
2013	Dec	22.8
2014	Jan	14.4
2014	Feb	13.8
2014	Mar	10.5
2014	Apr	4.5

Table 1. Table showing the average EPCP developing time. The data shows the time required to create the EPCP document per month. The average time is 18.0 days, with a standard deviation of 10.5 days.

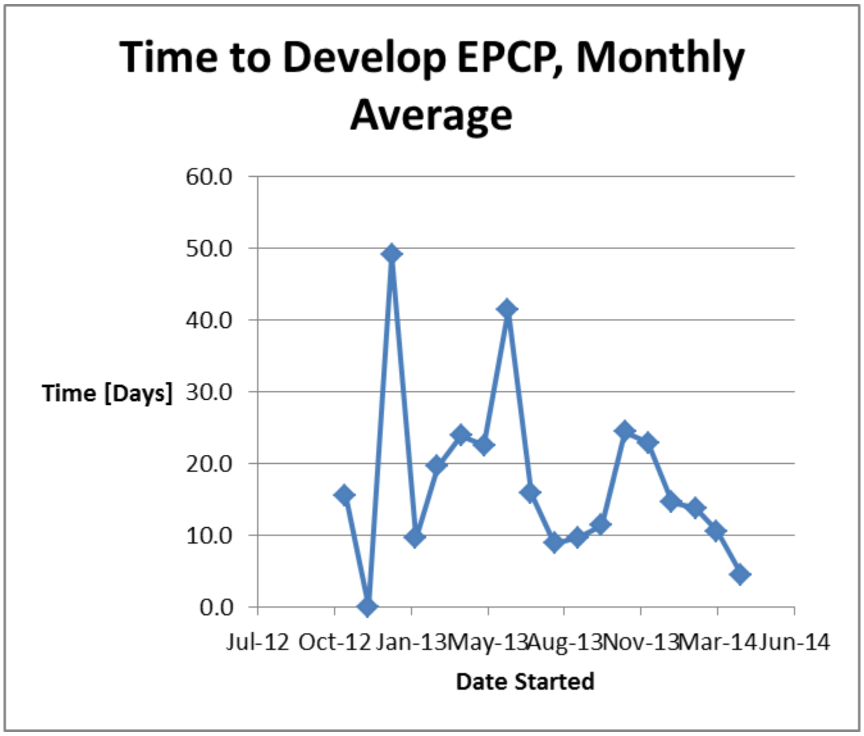

Figure 1. Shows the time for NSSA to develop an EPCP TWD, averaged monthly.

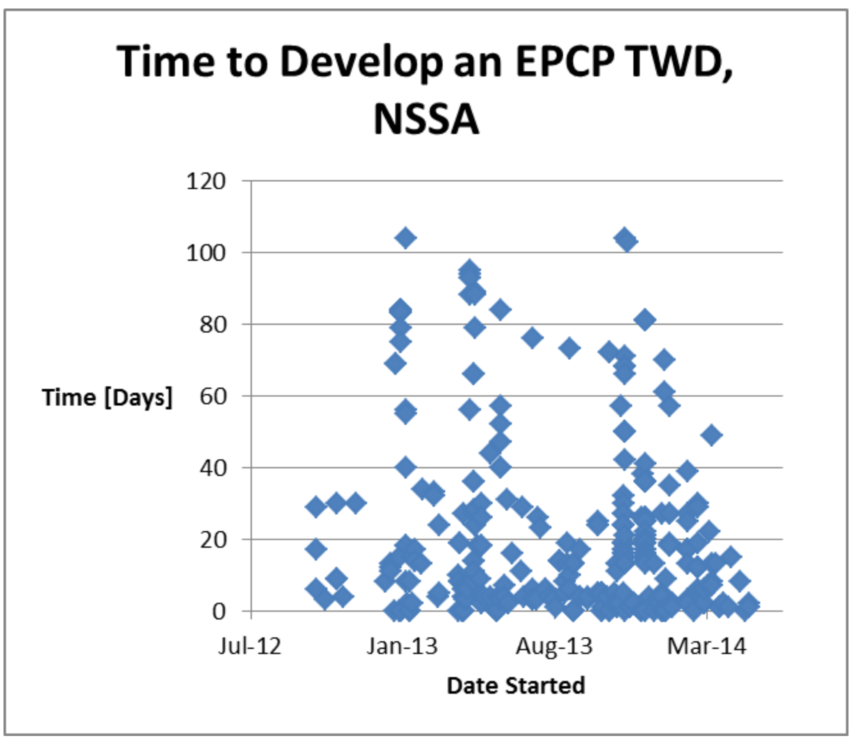

Figure 2. Shows the time for NSSA to develop an EPCP TWD, averaged daily.

A histogram of the time to develop an EPCP displays the frequency of the durations of the time to generate the EPCP TWD. Figure 3 shows this histogram. The most frequent durations are below ten days. The minimum duration is zero days, and the maximum is 104 days. The author suspects that this phase could be accomplished in zero days because the EPCP is being reused. The mean is 26.0 days.

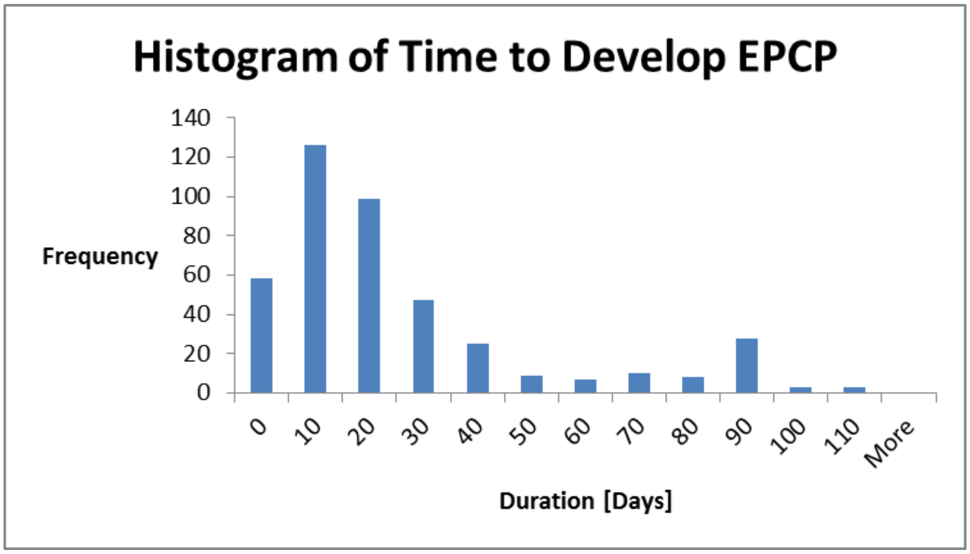

Figure 3. Histogram of time to develop EPCP. The most frequent durations are below ten days.

b. Time to Review the EPCP Documentation

Once an EPCP TWD is developed, it must be reviewed. The average time to review an EPCP when averaged across each day was 4.4 days with a standard deviation of 17.8 days. There were two data points that were more than three standard deviations from the mean. These two observations were discarded from this analysis. The updated average time to review an EPCP when averaged across each day was 3.3 days, with a standard deviation of 4.0 days. The minimum was zero days, and the maximum was 26 days. There were 413 observations. The R-squared value was 0.0175, and indicates that there is not a statistically significant trend over time for this data.

The review time was averaged per month. The average time to review an EPCP when averaged across each month was 3.2 days with a standard deviation of 2.3 days.

The average monthly data is shown in Table 2 and graphed in Figure 4. The average daily data is graphed in Figure 5. Figures 5 and 6 show the data after discarding the outliers.

Average Time for NSSA to Review an EPCP TWD per Month		
Year	Month	Average Time to Review [Days]
2012	Nov	10.7
2012	Dec	-
2013	Jan	1.1
2013	Feb	1.9
2013	Mar	2.2
2013	Apr	2.5
2013	May	1.9
2013	Jun	3.2
2013	Jul	2.5
2013	Aug	4.7
2013	Sep	1.4
2013	Oct	2.7
2013	Nov	5.3
2013	Dec	4.5
2014	Jan	2.7
2014	Feb	3.4
2014	Mar	2.1
2014	Apr	1.5

Table 2. This table shows the average EPCP reviewing time per month. The average time is 3.2 days, with a standard deviation of 2.3 days.

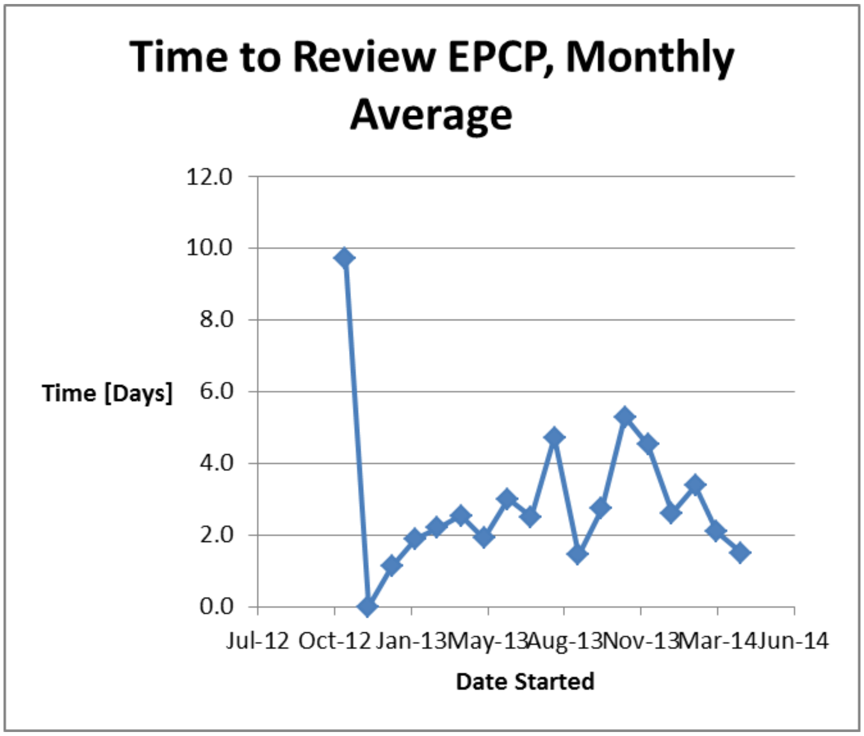

Figure 4. Shows the time for NSSA to review an EPCP TWD, averaged monthly.

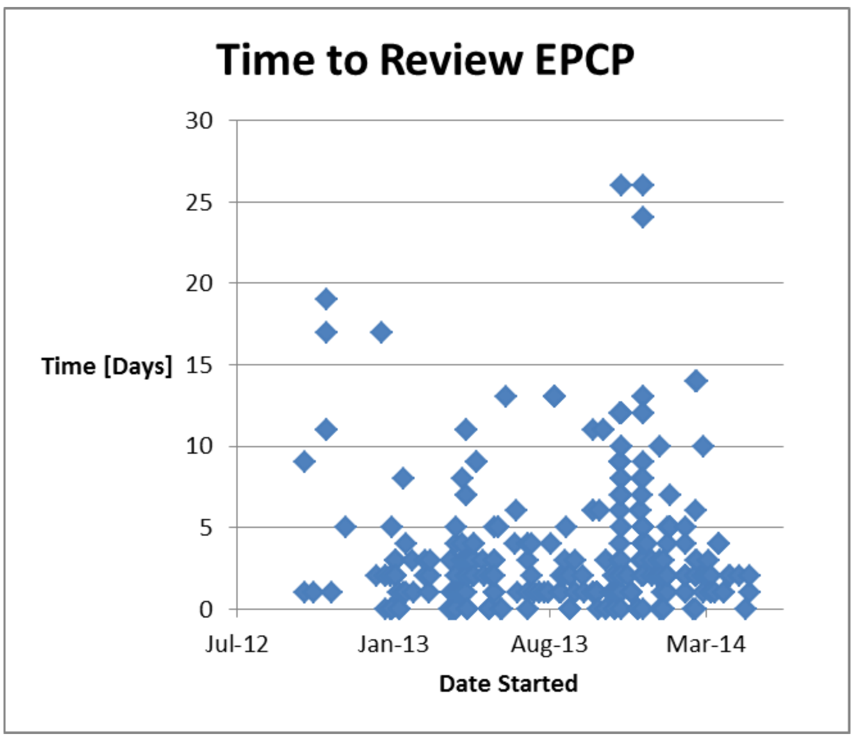

Figure 5. This figure shows the time for NSSA to Review an EPCP TWD.

There is no obvious trend in the average review time from fiscal year 2012 to 2014 once the outliers are eliminated. A regression on the data confirmed that there is no statistically significant trend over time since the R-squared value was 0.0175. It is possible that an improvement may be seen in the future as a result of learning curve.

A histogram of the time to review an EPCP displays the frequency of the durations of the review time for the EPCP TWDs. Figure 6 shows this histogram. The most frequent durations are between 5 and 9 days. The minimum duration is zero days, and the maximum is 26 days. The author suspects that this phase could be accomplished in zero days because the EPCP is being reused or the duration lasted less than one day. The mean is 5.3 days.

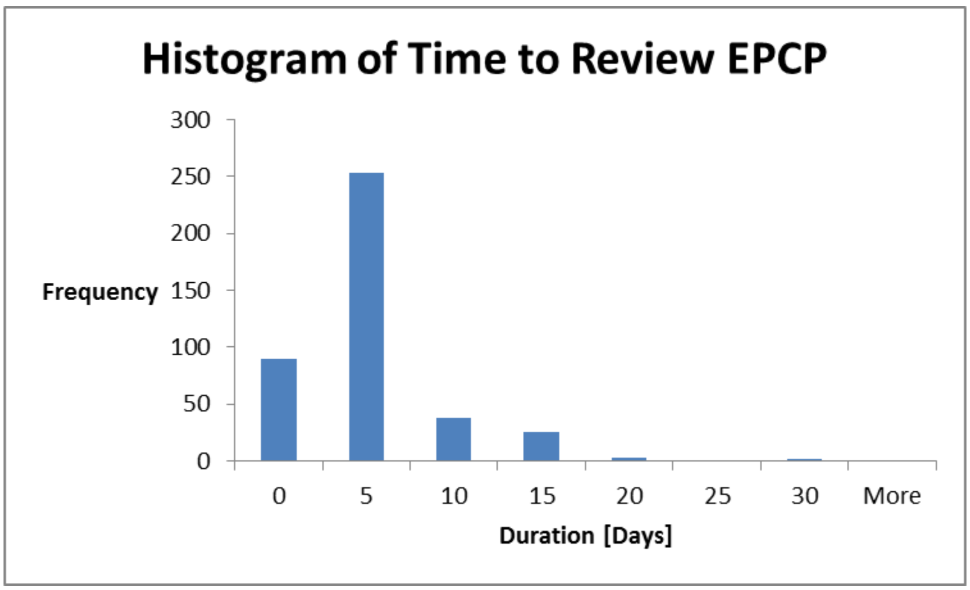

Figure 6. Histogram of the time to review EPCP. The most frequent durations are between 5 and 9 days.

c. Time to Correct EPCP Documentation

If errors are discovered during the review of the EPCP TWD, it must be corrected. The average time to correct an EPCP was 2.7 days, with a standard deviation of 7.2 days. There were five data points that were more than three standard deviations from the mean. These five data points were discarded from this analysis. The updated average time to correct an EPCP when averaged across each day was 2.2 days, with a standard deviation

of 4.8 days. NSSA started to track EPCP corrections starting in fiscal year 2013. The minimum was zero days, and the maximum was 24 days. The author suspects that this phase could be accomplished in zero days because the EPCP is being reused or the duration lasted less than one day. There were 408 observations. The time to correct was averaged per month. The average time to correct an EPCP when averaged across each month was 2.2 days with a standard deviation of 2.4 days. The average monthly data is shown in Table 3 and graphed in Figure 7. The individual EPCP data over time is shown in Figure 8.

Average Time for NSSA to Correct an EPCP TWD per Month		
Year	Month	Average Time to Correct [Days]
2012	Nov	0.0
2012	Dec	-
2013	Jan	1.0
2013	Feb	2.4
2013	Mar	0.8
2013	Apr	1.1
2013	May	1.1
2013	Jun	0.1
2013	Jul	1.3
2013	Aug	4.6
2013	Sep	3.7
2013	Oct	10.0
2013	Nov	1.2
2013	Dec	1.1
2014	Jan	2.5
2014	Feb	3.5
2014	Mar	1.9
2014	Apr	1.2

Table 3. This table shows the average EPCP correcting time for NSSA per month. The average time is 2.2 days, with a standard deviation of 2.4 days.

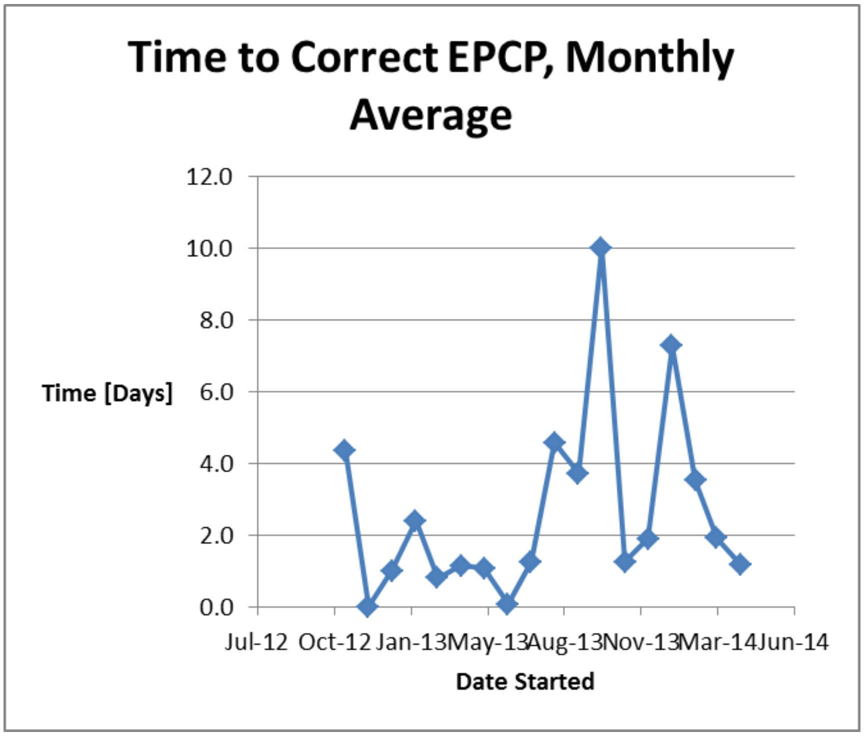

Figure 7. Shows the time for NSSA to correct an EPCP TWD, averaged monthly.

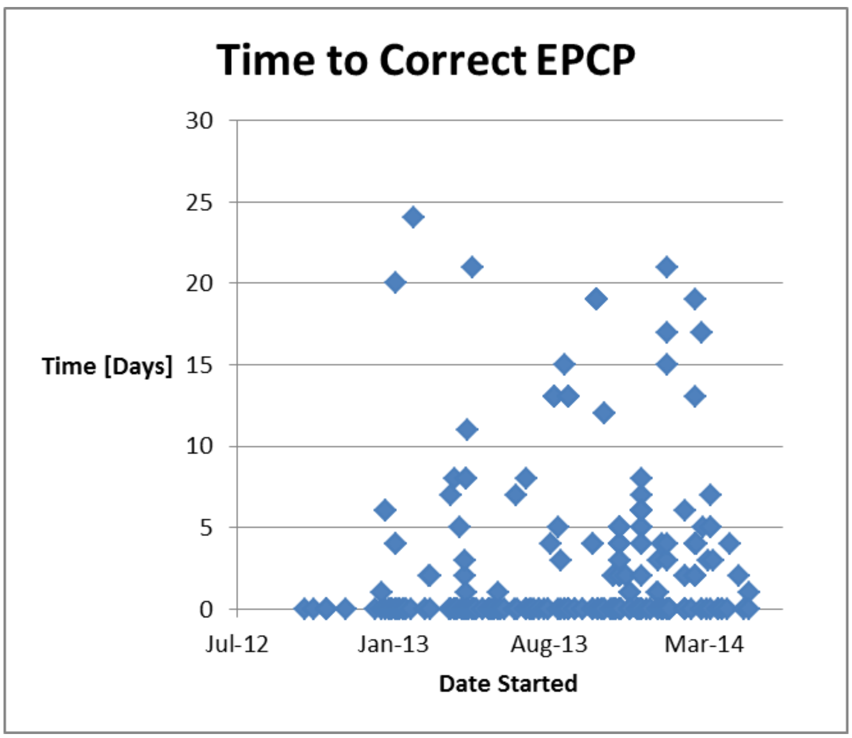

Figure 8. This figure shows the time for NSSA to correct an EPCP TWD.

The average time for NSSA to correct an EPCP TWD may have increased slightly as time passed from fiscal year 2013 to 2014, however, when outliers are removed, no trend is obvious. A regression analysis of the data confirmed that there was no statistically significant trend over time since the R-squared value was 0.0048.

A histogram of the time to review an EPCP displays the frequency of the durations of the correct time for the EPCP TWDs. Figure 9 shows this histogram. The most frequent durations are below five days. The minimum duration is zero days, and the maximum is 24 days. The author suspects that this phase could be accomplished in zero days because the EPCP is being reused or the duration lasted less than one day. The mean is 2.8 days.

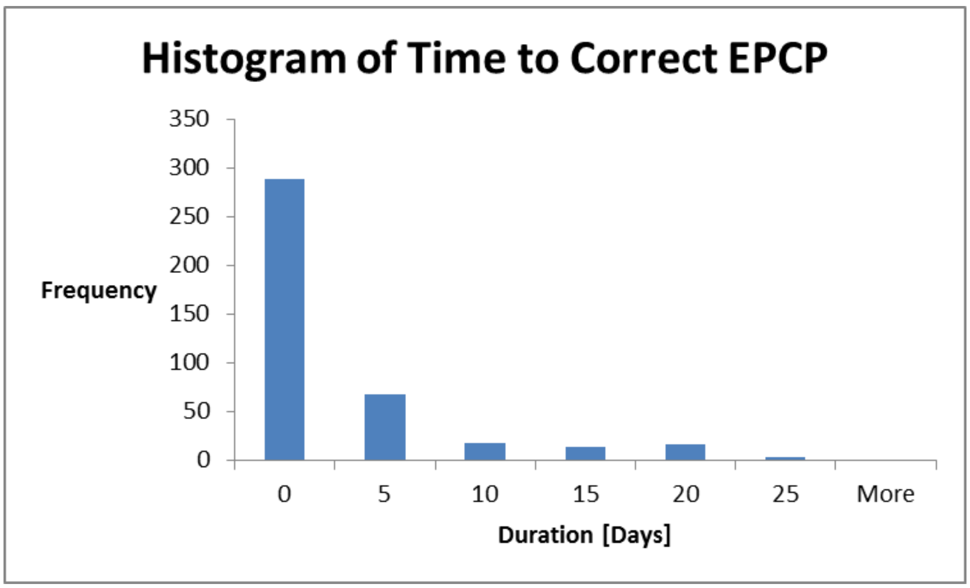

Figure 9. Histogram of the time to correct EPCP. The most frequent durations are below five days.

d. Total Administrative Time for EPCP Documentation

The total time to develop, review, and correct indicates how long the EPCP approval process takes. The average EPCP administrative time required when averaged across each day was 27.7 days, with a standard deviation of 26.1 days. The minimum was zero days, and the maximum was 107 days. The author suspects that this phase could be

accomplished in zero days because the EPCP is being reused or the duration lasted less than one day. There were 1075 observations.

The total administrative time was averaged per month. The average EPCP administrative time when averaged across each month was 14.3 days, with a standard deviation of 15.0 days. This data is shown in Table 4 and graphed in Figure 10. The total administrative time that was averaged daily is shown in Figure 11.

A histogram of the total administrative EPCP time displays the frequency of the durations of the total administrative time for the EPCP TWDs. Figure 12 shows this histogram.

Average Total Administrative Time for NSSA to Obtain an Approved EPCP TWD per Month		
Year	Month	Average Time to Correct [Days]
2012	Nov	3.2
2012	Dec	
2013	Jan	29.9
2013	Feb	3.0
2013	Mar	5.4
2013	Apr	17.0
2013	May	18.4
2013	Jun	17.9
2013	Jul	14.7
2013	Aug	11.0
2013	Sep	12.7
2013	Oct	19.0
2013	Nov	24.1
2013	Dec	24.4
2014	Jan	16.1
2014	Feb	16.7
2014	Mar	8.3
2014	Apr	1.7

Table 4. This table shows the average monthly total time for NSSA to develop, review, and approve an EPCP. The average time is 14.3 days, with a standard deviation of 15.0 days.

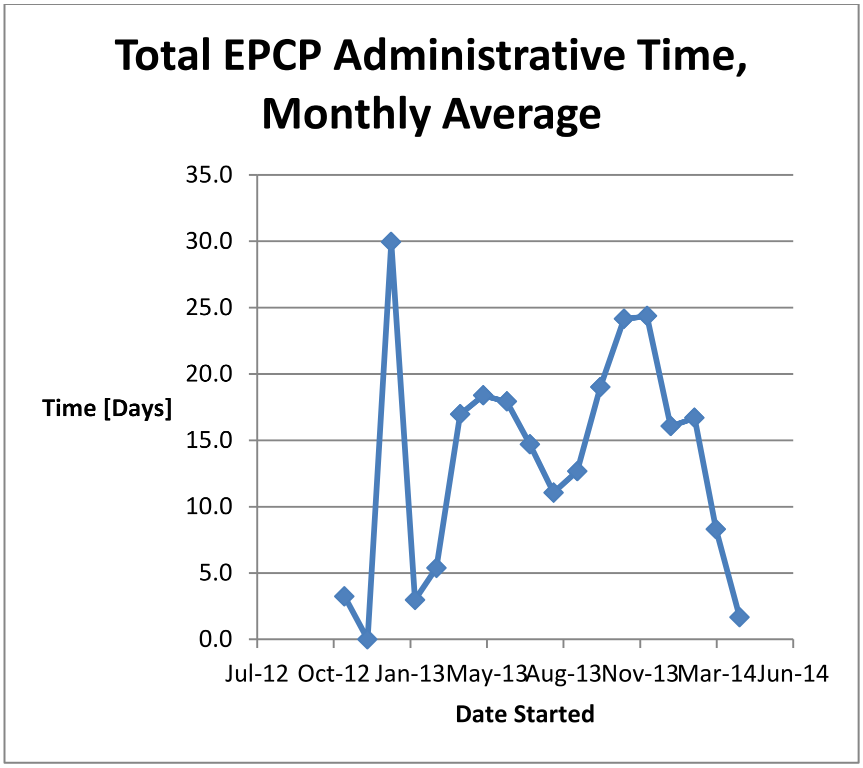

Figure 10. Shows the administrative EPCP time for NSSA, averaged monthly.

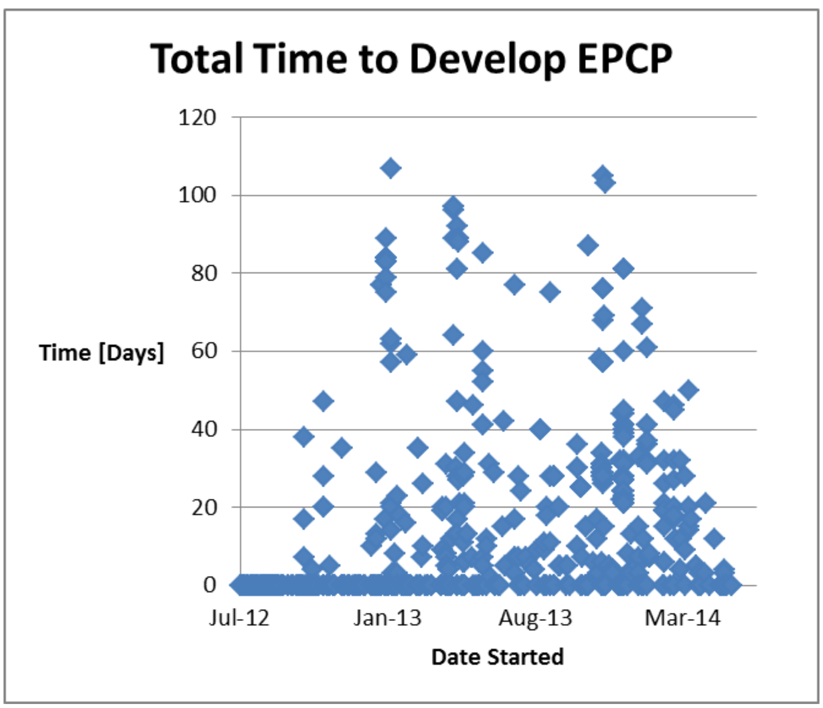

Figure 11. This figure shows the total time for NSSA to develop, review, and correct an EPCP TWD.

When evaluating the total time for each EPCP across fiscal years 2012 to 2014, the average total time was 27.7 days, and the standard deviation was 26.1 days. The average total time for NSSA to develop, review, and correct an EPCP TWD seemed to increase from fiscal year 2012 to 2014. However, once the individual data are plotted in Figure 11 and the outliers are removed, no trend is obvious. Regression analysis of the data confirmed that there was no statistically significant trend over time since the R-squared value was 0.0405.

A histogram of the administrative EPCP time displays the frequency of the durations of the administrative time for the EPCP TWDs. Figure 12 shows this histogram. The most frequent durations are between 30 and 39 days. The minimum duration is zero days, and the maximum is 107 days. The author suspects that this phase could be accomplished in zero days because the EPCP is being reused or the duration lasted less than one day. The mean is 31.7 days.

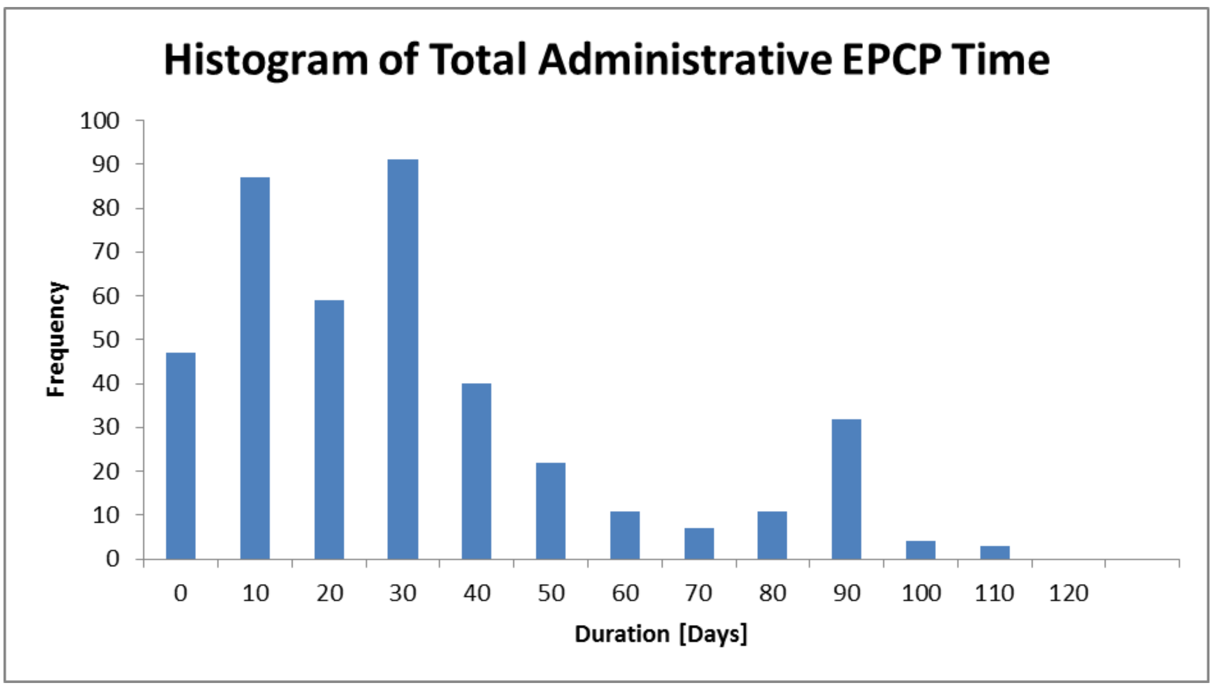

Figure 12. Histogram of the total EPCP administrative time.

From the histogram in Figure 12, each duration bin was converted to a percentage by dividing that bin's frequency by the total frequency. Figure 13 shows the cumulative

distribution for the total administrative EPCP time. The duration that will provide 75% confidence is 36 days, meaning that there is a 25% risk that an EPCP will take longer than 36 days.

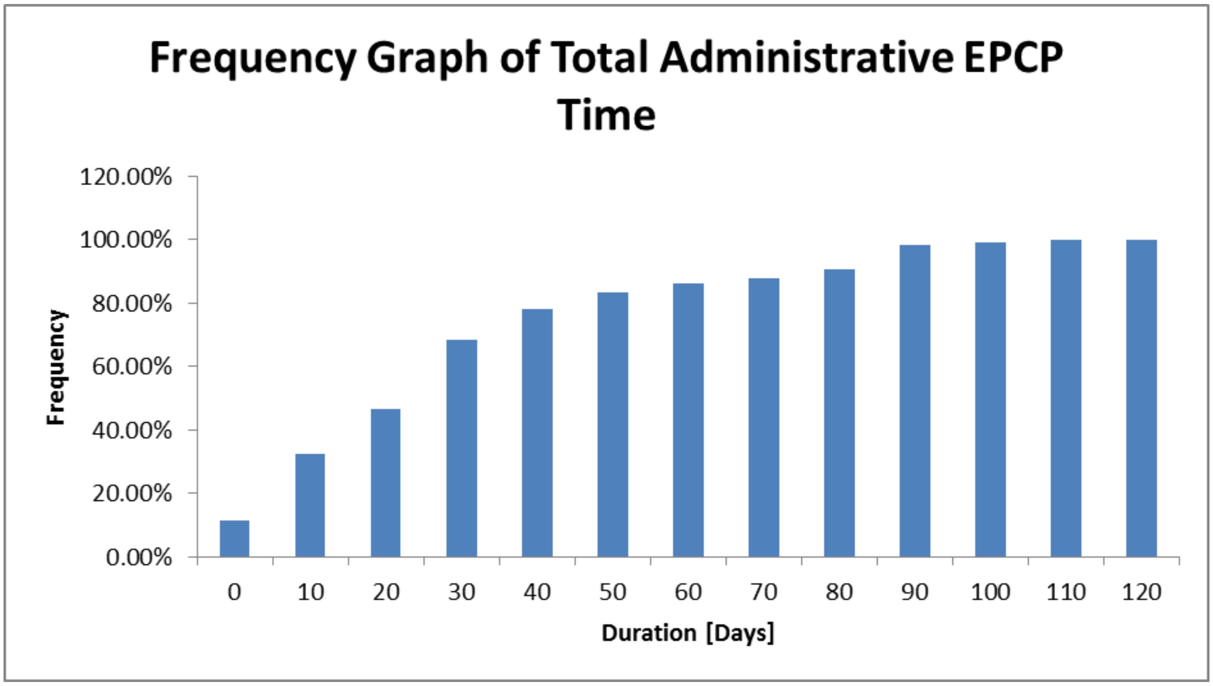

Figure 13. Frequency Graph of Total Administrative Time

When evaluating the total time for each EPCP across fiscal years 2012 to 2014, the average total time was 27.7 days, with a standard deviation of 26.1 days. This time cost is experienced for all work on critical systems. When compared to a scenario that does not require approved procedures prior to commence work, this time cost is a significant amount of time to add onto each work order for critical systems. However, efficient planning can mitigate this cost since the documentation process can occur anytime. If executed early, the EPCPs can be approved before work is scheduled to occur. Early EPCP approval would decrease the chance that work on critical systems would be delayed due to an unapproved EPCP. The delay would be limited to unanticipated work on critical systems.

B. EPCP REUSE

Reusing EPCPs occurs when a previously approved EPCP becomes the starting point for another EPCP for a similar or the same system. Reuse should tend to decrease the amount administrative time since the previous approval process would have fixed the majority of errors. By starting the development phase with a previously approved EPCP, it is likely that the administrative will have shorter durations. The data from NSSA shows that the EPCP reuse rate was 6.88%.

Reuse of EPCPs would help to decrease the total time cost to arrive at an approved EPCP. Of the EPCPs that were reused, almost 25% (24.32%) of the reused EPCPs needed changes. Seventy-five percent of the reused EPCPs did not require changes. This indicates a possible time cost saving by reusing EPCPs. Since reused EPCPs require little or no work to develop, 75% of reused EPCPs would not require the development duration that averages 31.7 days.

C. TIME TO EXECUTE THE APPROVED EPCP

Once an EPCP TWD has been approved, work may commence on the critical system. When conducting the work, the technician must have the approved EPCP with him. The technician must refer to the approved EPCP in order to ensure full compliance with the document. This process generally will result in the work taking longer to accomplish than if the technician conducted the work by relying on his experience and judgment. This may not be true if relying on the technician’s experience and judgment results in a critical system failure.

D. ERROR RATES

The amount of errors on each EPCP is unknown. The author recommends that the error rate of EPCPs be studied to identify root causes and possible improvements. NSSA reported errors on 11% of their EPCPs. The error rate may be influenced by the amount of EPCP reuse. An increase in EPCP reuse should result in fewer errors made. The EPCP that is being copied is one that has been approved and thus, has gone through the process of correcting any errors in the document.

E. SUMMARY

The time cost of the EPCP program was investigated by examining the duration of the three phases of the administrative part of the EPCP: development, reviewing, and correction. Data from NSSA concerning the amount of time each EPCP spent in these three phases from part of fiscal year 2012 to part of fiscal year 2014 was analyzed. Monthly averages and histograms were calculated for each phase and data over time was examined for possible trends. No statistically significant trends were found.

Data from the three phases was summed to obtain the total administrated EPCP time. The average EPCP administrative time required was calculated to be 27.7 days, with a standard deviation of 26.1 days. A frequency graph was created to determine that the duration that will provide 75% confidence of on-time completion is 36 days.

IV. OTHER FACTORS THAT CAUSE CRITICAL SYSTEM DOWNTIME AND MAINTENANCE AVAILABILITY EXTENSIONS

There are other factors that may contribute to critical system failures and maintenance availability extensions. Three of these factors, testing failures, parts availability and scheduling are discussed in this chapter.

A. TESTING FAILURES

Testing during maintenance availabilities ensures that the systems function according to their required specifications after work has been conducted. If the system fails its tests during maintenance availabilities, they may cause delays that can affect the critical path of work. The critical path of work is the sequence of tasks that drive the length of time that the maintenance availability takes. A delay to any portion of the critical path will result in the completion day being pushed back by that delay amount. Testing failures can occur due to parts failure, inadequate work executed, or testing requirements that are unachievable.

If a test fails, one of two options must occur. The first option requires rework on the system in order to conduct a successful test that meets the testing requirements. This option usually means delays that are not part of the original availability time frame. If these delays affect the critical path of the maintenance availability, a maintenance availability extension is likely to occur.

Testing failures can occur due to parts failure, inadequate work executed, or testing requirements that are unachievable. If the testing failure occurred due to a parts failure, the most common remedy is to replace the malfunctioning part. If the part is carried as a spare or readily available, the delay should be minimal. If the part is more difficult to obtain, the delay will likely be significant if it is on the critical path. Without the USN and contractor leadership exerting influence to expedite the arrival of the needed part, a delay in the completion of the maintenance availability will be likely. Some possible reasons the part would be difficult to obtain could be that the manufacturer discontinued or changed the part, the manufacturer went out of business, the part must be

refurbished by the contractor and returned to the ship, or a small quantity of parts must be shared among numerous ships.

The second option when a test failure occurs is that the USN technical authority approves a deviation to the testing requirements. This option is difficult and rare to achieve. By approving a deviation from the testing specification, the technical authority is accepting a significant amount of risk. If an equipment issue arises that is related to the approved deviation, the technical authority will likely be held partially or fully responsible. The approval to deviate from the technical requirements is most likely to occur if the testing specification is incorrect, unattainable, or unreasonable.

A failed test can usually be retested at any time. Once the planned solution has been implemented, a retest can occur. Exceptions may occur if the test requires specific conditions that cannot always be recreated. An example of these conditions is a test during Sea Trials that requires the ship to be moving at a certain speed through water.

B. PARTS AVAILABILITY

The ability of a ship conducting a maintenance availability to obtain needed parts from the logistics system can affect the probability of an on time completion. The GAO determined through a questionnaire that the "most common problem that caused K-alts to not be installed was a lack of material availability" (United States Government Accountability Office 1991, 15). K-alts is short for Title K ship alterations, complex modernization projects that occur during maintenance availabilities (United States Government Accountability Office 1991, 9). A K-alt is a Chief of Naval Operations (CNO) approved change that either "provides a military characteristic, upgrades existing systems or provides additional capability not previously held" (Global Security 2011). K-alts vary from installing steam piping drains to installing special hull treatment.

The lack of material availability means "material was not received in time to be installed or the material received was defective" (United States Government Accountability Office 1991, 15). New parts may need to be ordered during a maintenance availability in order to replace broken parts or to conduct modernization. Delays in

receiving the parts, mistakes in the parts ordering process, and parts taken by a higher priority ship can affect and hinder the progress of the ship's maintenance availability.

1. Delay in Receiving Parts

The prime or sub-prime contracting companies are typically responsible for ordering the parts needed for the maintenance and modernization processes during a maintenance availability.

Once the prime or sub-prime contractor has ordered the parts, they will be delivered to the contractor. The estimated delivery time may be too long. The delivery may also exceed the estimate. These scenarios are likely to cause delays. If the delays affect a system on the critical path, the completion of the ship's maintenance availability has a high probability of being pushed back.

2. Mistakes in Parts Ordering Process

During the process to order parts, there are at least three types of errors that can also contribute to a ship's maintenance availability delays: incorrect parts ordered, incorrect parts delivered, and parts ordered more than once.

If the prime or sub-prime contractor orders a part that is not needed or incompatible with the system, the wrong part has been ordered. This error causes a large amount of time to be lost since the error is usually identified once the part has been received. If this scenario arises, the correct part will need to be ordered and the contractor must wait for the correct part to arrive.

Another scenario involves the correct part being ordered, but the wrong part is received. This error is difficult to avoid since the cause lies either with the logistics system used to order the part or with the company that manufactured or sent the part. If the problem is systemic within the logistics system or within the manufacturer, the solution could require a short or long period of time to rectify. This would depend on the specific case for the part in question.

Without proper tracking of the parts that are ordered, it is possible and sometimes likely for the needed part to be ordered by different entities. The GAO recommended

“that the procedures be strengthened to ensure that material was not ordered more than once” (United States Government Accountability Office 1991, 11). Ordering too many quantities of the needed part does not directly cause delays in a maintenance availability. However, it causes an inefficient process that is difficult to manage. If uncontrolled, ordering multiple copies of the desired part affects the budget, which indirectly contributes to a ship completing the maintenance availability on time.

3. Part Taken by a Higher Priority Ship

All ships fall under a maintenance priority hierarchy depending on their current mission. Typically, this priority refers to a ship’s need to rapidly receive needed resources. Ships that are deployed and conducting operations receive the highest priority. Ships that are in port and not planning to deploy for relatively long time have a lower priority. If a ship that is high priority has an equipment failure, that ship’s priority status may cause the USN to take that needed part from a lower priority ship. Ships conducting maintenance availabilities have a higher priority than many ships in port since the USN wants to avoid delays for these ships. However, it is possible for a ship conducting a maintenance availability to be forced to give a part or equipment to a higher priority ship.

C. SCHEDULING

According to the Government Accountability Office (United States Government Accountability Office 1991), the scheduling of ships’ maintenance availabilities is important in minimizing the frequency and magnitude of_ maintenance availability extensions and delays. If too many maintenance availabilities are scheduled at any time, it is likely that the ship’s crew, contractors, and government representatives will be overloaded. If this scenario arises, the probability of mistakes, inadequate work, and insufficient management increases. A root cause of these negative outcomes is the lack of time to execute the maintenance availability. In 1987, 32 out of 244 ships, or 13 percent, had modernization work that was canceled or moved to another year. Of these 32 ships, 13 ships, or 41 percent, changed their deployment schedule. The reasons that the remaining ships experienced a cancellation or were moved to another fiscal year were

unknown. These reasons for the moving of modernization work were not known to Navy program officials (United States Government Accountability Office 1991).

Also an additional 53 ships, or 22 percent, were added to the fiscal year 1987 program after the 1987 fiscal year budget was submitted to the Congress. The USN seeks to avoid late additions to the program. This is because of the extensive planning process that is required to prepare for the installation of the K-alts (United States Government Accountability Office 1991).

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V. INFORMATION MANAGEMENT

Record keeping is important for management to be able to provide adequate oversight on a complex system. When each maintenance availability is completed, "all work within the availability must be documented and certified" (Lawson 2012c). Fleet Modernization Program Management Information System (FMPMIS) "reports the installation status of each K-alt and is supposed to list each ship, all K-alts applicable to the ship, and whether the K-alts have been completed" (United States Government Accountability Office 1991, 18). This information system is tasked with efficiently managing the USN's ship maintenance availabilities. However, the GAO determined that FMPMIS was not accurate when the system was compared to the responses to the GAO's questionnaire.

The GAO assessed that "the Navy does not maintain accurate and complete records needed to plan modernization work and measure the results of the program, even though it has procedures and management information systems designed to capture these data" (United States Government Accountability Office 1991, 4). The GAO noted that it was "unable to determine the reasons for many changes in the program's schedule because central records were not maintained and there were inadequacies in the Navy's management information system" (United States Government Accountability Office 1991, 3). The GAO also stated that it was "unable to determine how many modernization programs that were included in the fiscal year budget, but were not completed as part of that year's program, were completed as part of other years' modernization programs" (United States Government Accountability Office 1991, 3). The GAO indicated that "the Navy does not routinely measure the results of its Fleet Modernization Program or maintain accurate and complete information on the status of planned ship modernization projects" (United States Government Accountability Office 1991, 3).

A. GAO FINDINGS

In 1991, the GAO created "a questionnaire to evaluate the Fleet Maintenance Program of 75 selected ships since basic data was not_ available" (United States

Government Accountability Office 1991, 4). 268 questionnaires obtained information from "27 Navy shipyards and activities" (United States Government Accountability Office 1991, 12). The results showed a discrepancy between the answers to the GAO's questionnaire and the data in the Navy's management information system. The results of the questionnaire showed "1,308 projects had been completed, but the Navy's management information system showed only 308 as completed" (United States Government Accountability Office 1991, 4). Around "630 of the projects were not listed in the Navy's information system, and there was no record of any modernization work for several ships, although the GAO's questionnaire results indicated that 38 alterations had been installed on them" (United States Government Accountability Office 1991, 4).

It is possible that responses to the GAO's questionnaire were inaccurate. However, it is also conceivable that the discrepancies observed by the GAO indicated a tracking and monitoring process that required improvement. The author suggests that the latter is more likely to be accurate since the GAO has observed similar deficiencies in the past. In 1976 and 1982, "both GAO reports identified problems with deferrals of ship alterations and poor planning practices" (United States Government Accountability Office 1991, 4). Even though the "Navy made improvements in response to the GAO's recommendations, it was evident that the same problems existed" (United States Government Accountability Office 1991, 4). The GAO report suggests that "if the management information system provided timely and complete information on these problems to Navy management officials, prompt corrective action might have been taken to resolve them" (United States Government Accountability Office 1991, 4).

a. Departure Reports

All "Navy activities that install K-alts are require to file a departure report within 60 days after modernization work has been completed on each ship" (United States Government Accountability Office 1991, 19). These Departure Reports "provide the only verification that K-alts have been installed" (United States Government Accountability Office 1991, 19). In fiscal year 1987, "56 of the 75 ships examined in detail for which departure reports were required, 27 reports had not been prepared." Officials at one

"Supervisor of Shipbuilding, Conversion, and Repair office said they had not prepared departure reports for years because of personnel shortages" (United States Government Accountability Office 1991).

b. Escrow Accounts

The Naval Sea Systems Command's FMP Management Office "uses the escrow account to track the changes to modernization work authorized for each ship" (United States Government Accountability Office 1991, 19). The funds for all "K-alts added to or deleted from the program are supposed to be recorded in these accounts" (United States Government Accountability Office 1991, 19). The GAO discovered "many instances in which K-alts had been cancelled but still had funds authorized in the escrow account" (United States Government Accountability Office 1991, 19). Out of 24 cases study ships, the GAO identified 13 ships which did not have accurate escrow account information (United States Government Accountability Office 1991, 19).

B. NAVY RESPONSE

In 1991, the GAO noted that the "program's management information system must provide timely information to managers to support planning, programming, budgeting, executing, and evaluating the program" (United States Government Accountability Office 1991, 4). In 1991, the Navy's "official automated data base for FMP management, intended to provide timely information to support planning, programming, budgeting, and executing the program" was FMPMIS (United States Government Accountability Office 1991, 18).

The USN currently has an organization that has the goal of addressing these gaps. Naval Sea Systems Command (NAVSEA) Regional Maintenance Office (NRMO) "serves as a primary point of contact for critique notification to Commander, Navy Regional Maintenance Center (CNRMC), and provides independent oversight of surface ship maintenance with particular focus on critical systems" (Lawson 2012b). NRMOs "began in May 2011, following several negative trends in surface ship maintenance" (Lawson 2012b). Commander, Naval Sea Systems Command in 2011 Vice Admiral Kevin McCoy "directed third party oversight of non-nuclear surface ship maintenance

similar to the role of NAVSEA Shipyard Representative's Office and Naval Reactors Representative's Office at the public shipyards" (Lawson 2012b). Commander, Navy Regional Maintenance Centers (CNRMC), Rear Admiral Gale stated that the "NRMO organizations are aimed at supporting our unwavering goal of improving first time quality, enhancing safety, reducing total operational costs, and more closely adhering to ships' maintenance schedules" (Lawson 2012b). Admiral Gale said, "The NRMOs support the surface ship maintenance community by reviewing maintenance and repair work to ensure adherence to quality, technical, and safety standards at the operational, intermediate, and depot levels" (Lawson 2012b).

NRMO's "are responsible for performing periodic surveillance of in-process work; conducting audits of areas of particular focus to the fleet such as procedure and work control compliance; attending EPCP ready to start (RTS) events" (Lawson 2012b). There are five NRMOs: "Norfolk Ship Support Activity Regional Maintenance Center in Norfolk, Virginia; Southeast Regional Maintenance Center in Mayport, Florida; Southwest Regional Maintenance Center in San Diego; Northwest Regional Maintenance Center in Bremerton, Washington; and Hawaii Regional Maintenance Center in Pearl Harbor, Hawaii" (Lawson 2012b).

CNRMC "implements the NRMOs" (Lawson 2012b). CNRMC's assistant director for technical oversight, Frank Murphy, who served in 2012 as the NRMOs' program manager stated, "the other NRMO offices share lessons learned and collaborate several times a week through phone conferences. They regularly confer to discuss the most effective ways to evaluate ship maintenance processes; implement quality improvement efforts, lower cost, improve safety, and shorten maintenance schedules." All of the NRMOs "work closely with ships' project teams to continually improve surface ship maintenance efforts in the areas of work control, safety and technical rigor oversight and management" (Lawson 2012b). Admiral Gale stated, "NAVSEA and NRMOs have worked collaboratively to improve the quality and schedules of non-nuclear surface ship maintenance by the enforcement of standards" (Lawson 2012b).

According to Admiral Gale, as a result of the NRMOs, there has been "marked improvements in root cause analyses and the critique processes, allowing CNRMC to

work with the RMCs to provide clarification of policies and standards for foreign material exclusion (FME)." Additionally, Admiral Gale stated, "The NRMO's efforts have also led to the identification of problems with machinery layup and planned maintenance system (PMS), as well as the identification of several safety related problems."

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VI. EPCP PROCESS RECOMMENDATIONS

The author recommends that the EPCP program be more efficient by increasing the number of EPCPs that are reused, decreasing the number of EPCP errors, involving subject-matter experts in EPCP documentation, and decreasing the EPCP administrative temporal impact.

1. EPCP Reuse

The author recommends that a greater effort be made to increase the number of EPCPs that are reused. The reuse of an EPCP means that a previously approved EPCP for the same or similar work for a system would be used as a starting point in the developing phase. The alternative would be to develop the EPCP document from the beginning. The contractors were observed in NSSA to develop 93% of the EPCPs. Due to this tendency of contractors being the entity that develops the EPCP, incentives should be used to encourage EPCP reuse. A possible incentive could be a savings sharing systems that pays the contractor to save money by reusing the EPCP. EPCP reuse was observed in the same organization to be almost 7%. This means that of all the EPCPs used for the surface ships in this organization, only 7% of the EPCPs were made based on previous EPCPs. Since each class of surface ship will tend to have similar critical systems, the author recommends the USN set a short term and long term goal for the amount of EPCP reuse.

2. Decrease EPCP Administrative Temporal Impact

One process that may be used to decrease the effect of the time to generate the EPCPs is to predict the work needed during a maintenance availability through analyzing the Preventative Maintenance System (PMS) records of the critical systems. The PMS conducted and its results can provide indications of the state of the critical system and which work will be required. This knowledge will allow the maintenance team to start the EPCP documentation process early and be less likely to encounter delays in work due to the EPCP administration process. The development, reviewing and correcting phases of work that is determined to be needed would be able to be accomplished well in advance of the start of the maintenance availability. This knowledge can also help prevent some

scenarios where the occurrence of critical systems equipment failures results in delays in the completion of the maintenance availability.

3. Involve Subject-Matter Experts in EPCP Documentation

The author also recommends that the technicians be involved in the EPCP documentation development phase. The author does not have data indicating the extent in which technicians are involved in the EPCP documentation phase. If the technicians are adequately involved, this recommendation is met. Since the technicians are the subject-matter experts and the people who will conduct the work, their input is valuable. The technicians may be able to identify errors in the EPCP that will not be discovered until much later in the process. These errors may not be detected at all before the work commences without the knowledge of the technicians. Using the technicians in the documentation development phase should decrease the duration of the development, reviewing and correcting phases since more accurate information should result in fewer errors and changes needed.

Through increasing the number of EPCPs that are reused, decreasing the number of EPCP errors, involving subject-matter experts in EPCP documentation, and decreasing the EPCP administrative temporal impact, the EPCP process will be likely to experience greater efficiency and success than the EPCP program without these improvements.

VII. CONCLUSIONS AND FUTURE RESEARCH

1. Conclusions

This study identified the costs and benefits of the EPCP program implemented by the Navy. The costs of the EPCP program are the increased time required to complete the work, greater funding requirements, decreased flexibility, and possible impact on the technicians. The benefits are a larger degree of accountability, lower probability of human error, and greater communication and coordination. Testing failures and parts availability may also contribute to critical systems failures and maintenance availability extensions.

In particular, the time impact of EPCPs was analyzed using EPCP records over an 18-month period between 2012 and 2014. The time to develop, review and correct an EPCP was evaluated, as well as the total time to complete an EPCP. The analysis found no statistically significant trends in the total administrative time, or in the development, reviewing and correction phase.

The average total time for each EPCP across fiscal years 2012 to 2014, was 28 days, with a standard deviation of 26 days. The 75% confidence value for the total administrative time of an EPCP is 36 days. Of the EPCPs that were reused, 75% of these EPCPs did not require changes.

The author recommends using the 75% confidence value for the total administrative time duration when planning a maintenance availability. Under estimating the total time to obtain an approved EPCP will likely result in delays and increased costs.

The author also recommends the USN increase the amount of EPCP reuse. This would be beneficial since 75% of reuse EPCPs did not require changes. This fact indicates that there would be significant time cost savings during the administrative EPCP process. This time cost savings would be applied to multiple work orders throughout a maintenance availability and will help to achieve the goal of finishing the availability under budget and on schedule.

2. Future Research

The author recommends obtaining and analyzing data concerning the EPCP program during years before 2012. This data may not have been tracked or may not be available. If the data is possible to obtain, it would either confirm some, many, or all of the conclusions of this paper or, equally revealing, it would contradict some, many, or all of these conclusions. The author also recommends continuing to gather, track, and analyze this data. Analyzing the data allows the USN to identify the strengths and weaknesses of the EPCP program. The author recommends tracking the cost and number of working hours associated with each EPCP. The author also recommends tracking the amount of errors discovered in each EPCP. This would assist in evaluating the cost of implementing an EPCP program.

This paper utilized data from Norfolk Ship Support Activity Regional Maintenance Center. The author recommends further work is done to evaluate the EPCP costs and benefits utilizing EPCP data from all five Regional Maintenance Centers: Norfolk Ship Support Activity Regional Maintenance Center, Southeast Regional Maintenance Center, Southwest Regional Maintenance Center, Northwest Regional Maintenance Center, and Hawaii Regional Maintenance Center.

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